

Reductions in Susceptibility of Channel Catfish, *Ictalurus punctatus*, to Enteric Septicemia of Catfish through Two Generations of Selection

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Selective breeding for disease resistance has had varied success in agricultural animals. In aquaculture, selection for disease resistance is ongoing in salmonids, carp, Japanese flounder, and catfish as well as in other fish and shellfish (Haskin and Ford 1979; Gjedrem 2000; Vandeputte 2003; Fuji et al. 2006). Improving disease resistance through selective breeding can be problematic because disease resistance is typically a complex trait and selection based solely on phenotypic response to challenge can be less than ideal (Gjedrem 1983; Beacham and Evelyn 1992). The nature of the challenge model may also affect heritability. Heritabilities are higher in experimental challenges in salmonids than in natural challenges with the same pathogens, with the exception of furunculosis (see review in Gjedrem 2000).

Enteric septicemia of catfish (ESC) is the most prevalent disease affecting commercial catfish operations in the southeastern USA (USDA 1997) and is caused by the bacterium *Edwardsiella ictaluri* (Hawke et al. 1981). The USDA–ARS Catfish Genetics Research Unit (Stoneville, MS, USA) has focused on genetic improvement of channel catfish, *Ictalurus punctatus*, through selective breeding since 1991. The early stages of the channel catfish breeding program at the USDA–ARS Catfish Genetics Research Unit focused on improvement of growth through strain comparison and within strain selection. This resulted in a joint release of germplasm to commercial catfish producers by U.S. Department of Agriculture–Agricultural

Research Service and Mississippi State University. This strain of channel catfish was designated the NWAC103.

Among the NWAC103 strain of channel catfish, there is considerable phenotypic variation among full-sib families and consistent family rankings within a year class for ESC susceptibility across multiple challenges (Wolters and Johnson 1994; Bilodeau et al. 2003, 2005). There are also differences in lysozyme activity and pathogen loads carried during challenge among families with large differences in susceptibility to ESC. Strain and species comparisons of catfish have also demonstrated a large range in susceptibility to ESC challenge (Bosworth et al. 1998, 2004).

Since the release of the NWAC103 strain, the selection program has been expanded to incorporate multiple traits, including growth, carcass yield, and ESC resistance. Each trait is assigned an equal weight. The current generation of fish (USDA303) is the result of two generations of family selection using multitrait selection.

The purpose of this study was to assess the effectiveness of the multitrait selection index for reducing susceptibility to ESC by comparing the second-generation selected strain (USDA303) of channel catfish to the unselected base population (NWAC103) during experimental challenge with *E. ictaluri*.

Materials and Methods

Selective Breeding

The NWAC103 base population was obtained from Uvalde National Fish Hatchery, Uvalde, Texas, USA. Full-sib families produced from the base population were evaluated for survival

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of juveniles following experimental challenge with virulent *E. ictaluri* in aquaria, growth to market weight (approximately 1.5 lb) in earthen ponds, and meat yield at market weight. A multitrait composite score for each family was determined by ranking families for each trait and assigning an equal weight to each trait. Additional selection was performed for growth by within-family selection of the largest males and females from families with the highest composite score. Following selection, all selected families/fish were mixed and distributed among spawning ponds where fish were allowed to mate at random. A randomly mated, unselected control line was also maintained.

From the NWAC103 line, the highest ranking 15 from a total of 77 families were selected. Subsequently, the highest ranking 16 from a total of 84 families evaluated were selected in the second generation to produce the USDA303 line. The cumulative selection differential (difference between mean of selected families and population average) for survival to ESC challenge was 22.3% (9.9% the first generation and 12.4% the second generation). However, because fish were selected based on family means, not individual performance, and because fish were allowed to mate at random within the selected line following selection, the realized cumulative selection differential may have differed from the reported cumulative selection differential.

Experimental Challenge

After two generations of selection, fish were allowed to randomly mate within the control line (NWAC103) and selected line (USDA303), and 62 full-sib USDA303 families and 29 full-sib NWAC103 families were compared for survival to ESC challenge. Thirty juvenile fish from each family were acclimated for 7 d in 120-L aquaria supplied with 26°C well water and then were exposed to virulent *E. ictaluri* (1.9×10^9 CFU/mL, confirmed by standard plate counts) with a 30-min immersion. Mortality was monitored for 21 d postexposure during which dead fish were removed daily from each aquarium. This protocol was repeated for an additional replicate trial. All fish were weighed prior to stock-

ing and were fed a standard catfish diet at 3% body weight once daily throughout the acclimation period and following the challenge.

Data Analysis

Percent survival for fish in each aquaria was determined at the end of the challenge and analyzed as a mixed-model ANOVA using the Mixed Procedure of SAS. The model included replicate challenge and line (selected vs. control) as fixed effects, family within line as a random effect, and mean weight of full-sib family as a covariate. Family within line was used as the error term in comparison of selected and control line postchallenge survival. Pearson product moment correlations between family survival from replicate challenges were determined to assess consistency of family performance. Differences between lines were declared significant at $P < 0.05$.

Results

The mean weight of fish was 24.03 ± 0.64 g, and there was no difference in weight between groups ($P > 0.05$). USDA303 catfish showed lower levels of mortality than NWAC103 catfish during replicate challenges ($P = 0.02$). Mean mortality levels during challenge were 50.2% for NWAC103 families and 39.9% for USDA303 families (Table 1). While the range of mortality levels was greater for the USDA303 families (3.3–90.0% compared to 11.7–88.3% for NWAC103), a greater proportion (51.7%) of the NWAC103 families had over 50% mortality compared to the USDA303 families (25.8%). Despite the large amount of variation in response to *E. ictaluri* challenge between families for both groups (Fig. 1), there was

TABLE 1. Mortality of NWAC103 and USDA303 channel catfish subjected to *Edwardsiella ictaluri* challenge.

Strain	Trial	Mortality (%)	SEM
NWAC103	1	44.7	4.3
	2	55.6	4.1
	Mean	50.2	
	1	37.6	2.6
USDA303	2	42.1	2.5
	Mean	39.9	

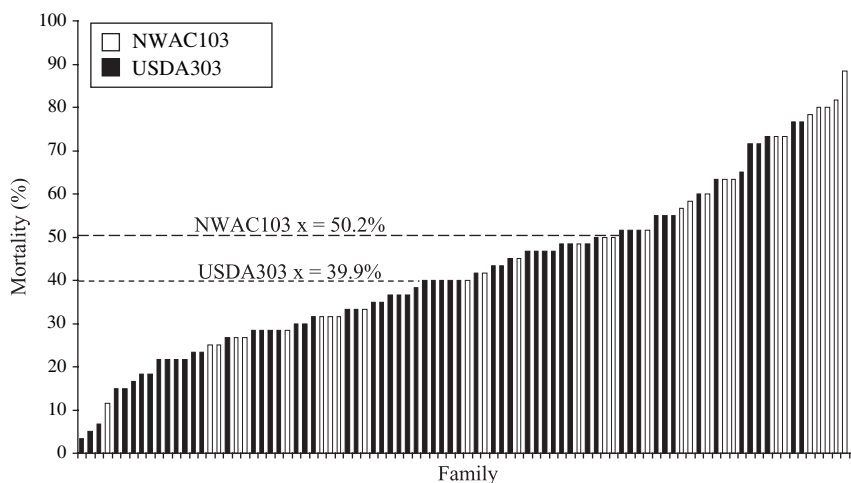


FIGURE 1. Mortality (%) of channel catfish families subjected to experimental *Edwardsiella ictaluri* challenge. A total of 29 families were tested for NWAC103 fish and 62 families for USDA303 fish.

a high correlation in response between replicate challenges for family rankings ($P < 0.0001$ for NWAC103 and USDA303 families).

Discussion

Disease resistance typically has lower heritability than growth rate and other traits in most aquaculture species. Low heritability can lead to slow progress with selective breeding. However, selection for disease resistance has been successful in Japanese flounder, common carp, salmon, and other aquaculture species (Kirpichnikov et al. 1993; Kolstad et al. 2005). Single-trait selection can potentially be problematic because performance of other traits may be compromised. There are examples of both positive and negative genetic correlations between growth and disease resistance in fish (Standal and Gjerde 1987; Gjedrem et al. 1991; Nilsson 1992; Henryon et al. 2002).

We utilized a multitrait selection index that incorporated not only susceptibility to ESC but also growth and carcass yield. After only two generations of selection, we have shown improvement in resistance to ESC of 10.3%. This value is lower than what has been found for improved growth (11% per generation) and reduction in frequency of early maturation (22% per generation) in various fish species.

There is still a large amount of variation in response to *E. ictaluri* challenge that is evident between families. The reduction in susceptibility to *E. ictaluri* challenge that we observed in aquaria may or may not translate to the commercial production environment (large earthen ponds). Our trials were conducted in a controlled environment in glass aquaria. In contrast, the pond environment contains numerous pathogens at any given time and is a dynamic ecosystem. The evidence presented here suggests that resistance to ESC is heritable. If the apparent genetic variation for ESC susceptibility can be capitalized upon through selective breeding, then improvements in ESC survivorship in the pond environment are likely.

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